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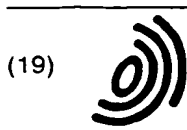
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(54) **Modular fuel injector and method of assembling the same**

(57) A fuel injector (100) for use with an internal combustion engine. The fuel injector (100) comprises a valve group subassembly (200) and a coil group subassembly (300). The valve group subassembly (200) includes a tube assembly having a longitudinal axis that extends between a first end (200A) and a second end (200B); a seat (250) that is secured at the second end (200B) of the tube assembly and that defines an opening; an armature assembly (260) that is disposed within the tube assembly; a spring (270) that biases the armature assembly (206) toward the seat (250); an adjusting tube (281) that is disposed in the tube assembly and that engages the spring (270) for adjusting a biasing force of the spring (270); a filter (284A) that is disposed at least within the tube assembly. The coil group subassembly (300) includes a solenoid coil (310) that is operable to displace the armature assembly (260) with respect to the seat (250). Furthermore, the valve group subassembly (200) includes a lift sleeve (255) to set a relative axial position between the seat (250) and the tube assembly. The armature face (260) is oblique to the longitudinal axis.

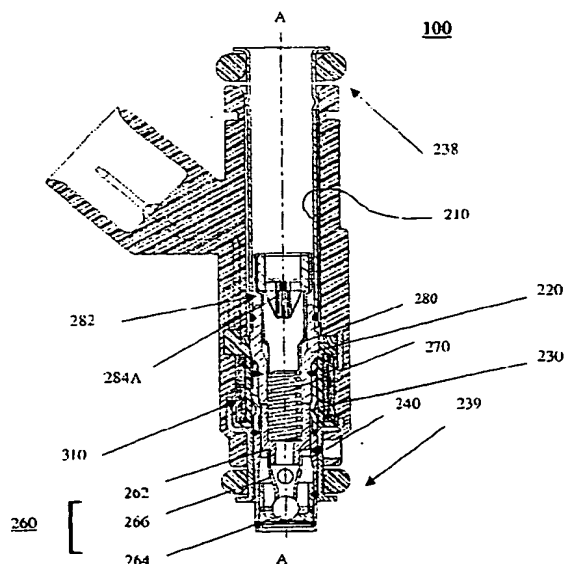
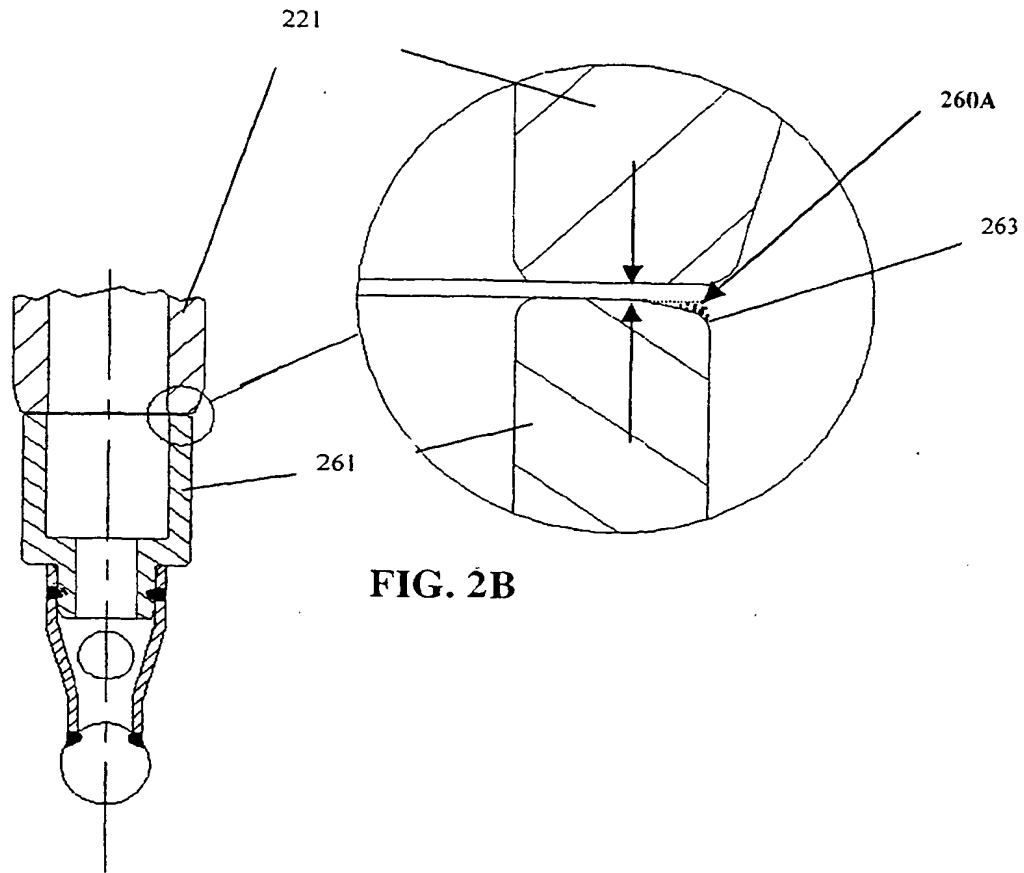


FIG. 1

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## Description

### Background of the Invention

[0001] It is believed that examples of known fuel injection systems use an injector to dispense a quantity of fuel that is to be combusted in an internal combustion engine. It is also believed that the quantity of fuel that is dispensed is varied in accordance with a number of engine parameters such as engine speed, engine load, engine emissions, etc.

[0002] It is believed that examples of known electronic fuel injection systems monitor at least one of the engine parameters and electrically operate the injector to dispense the fuel. It is believed that examples of known injectors use electro-magnetic coils, piezoelectric elements, or magnetostrictive materials to actuate a valve.

[0003] It is believed that examples of known valves for injectors include a closure member that is movable with respect to a seat. Fuel flow through the injector is believed to be prohibited when the closure member sealingly contacts the seat, and fuel flow through the injector is believed to be permitted when the closure member is separated from the seat.

[0004] It is believed that examples of known injectors include a spring providing a force biasing the closure member toward the seat. It is also believed that this biasing force is adjustable in order to set the dynamic properties of the closure member movement with respect to the seat.

[0005] It is further believed that examples of known injectors include a filter for separating particles from the fuel flow, and include a seal at a connection of the injector to a fuel source.

[0006] It is believed that such examples of the known injectors have a number of disadvantages. It is believed that examples of known injectors must be assembled entirely in an environment that is substantially free of contaminants. It is also believed that examples of known injectors can only be tested after final assembly has been completed.

### Summary of the Invention

[0007] According to the present invention, a fuel injector can comprise a plurality of modules, each of which can be independently assembled and tested. According to one embodiment of the present invention, the modules can comprise a fluid handling subassembly and an electrical subassembly. These subassemblies can be subsequently assembled to provide a fuel injector according to the present invention.

[0008] The present invention provides a fuel injector for use with an internal combustion engine. The fuel injector comprises a valve group subassembly and a coil group subassembly. The valve group subassembly includes a tube assembly having a longitudinal axis extending between a first end and a second end. The inlet

tube assembly a tube assembly having a longitudinal axis extending between a first end and a second end, the tube assembly including an inlet tube having an inlet tube face; a seat secured at the second end of the tube assembly, the seat defining an opening; a lift sleeve telescopically disposed within the tube assembly a predetermined distance to set a relative axial position between the seat and the tube assembly; an armature assembly disposed within the tube assembly, the armature assembly having an armature face, at least one of the armature face and the inlet tube face having a first portion generally oblique to the longitudinal axis; a member biasing the armature assembly toward the seat; an adjusting tube located in the tube assembly, the adjusting tube engaging the member and adjusting a biasing force of the member; and a first attaching portion. The coil group subassembly includes at least one electrical terminal; a solenoid coil operable to displace the armature assembly with respect to the seat, the solenoid coil being axially spaced from the at least one electrical terminal; a terminal connector axially connected to the at least one electrical terminal, the terminal connector electrically connecting the at least one electrical terminal and the solenoid coil; and a second attaching portion fixedly connected to the first attaching portion.

[0009] The present invention also provides for a method of assembling a fuel injector. The method comprises providing a valve group subassembly, providing a coil group subassembly, inserting the valve group subassembly into the coil group subassembly and connecting first and second attaching portions. The valve group subassembly includes a tube assembly having a longitudinal axis extending between a first end and a second end. The tube assembly includes an inlet tube having an inlet tube face; a seat secured at the second end of the tube assembly, the seat defining an opening; a lift sleeve telescopically disposed within the tube assembly a predetermined distance to set a relative axial position between the seat and the tube assembly; an armature assembly disposed within the tube assembly, the armature assembly having an armature face, at least one of the armature face and the inlet tube face having a first portion generally oblique to the longitudinal axis; a member biasing the armature assembly toward the seat; an adjusting tube located in the tube assembly, the adjusting tube engaging the member and adjusting a biasing force of the member; a first attaching portion. The coil group subassembly includes a solenoid coil operable to displace the armature assembly with respect to the seat; and a second attaching portion

### Brief Description of the Drawings

[0010] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate an embodiment of the invention, and, together with the general description given above and the detailed description given below, serve to explain features

of the invention.

[0011] Figure 1 is a cross-sectional view of a fuel injector according to the present invention.

[0012] Figure 2 is a cross-sectional view of a fluid handling subassembly of the fuel injector shown in Figure 1.

[0013] Figure 2A is a cross-sectional view of a variation on the fluid handling subassembly of Figure 2.

[0014] Figures 2B and 2C illustrate the surface shape of the end portion of the impact surfaces of the electro-magnetic fuel injector.

[0015] Figures 2D and 2E are exploded views of the components of lift setting feature of the present invention.

[0016] Figure 3 is a cross-sectional view of an electrical subassembly of the fuel injector shown in Figure 1.

[0017] Figure 3A is a cross-sectional view of the two overmolds for the electrical subassembly of Figure 1.

[0018] Figure 4 is an isometric view that illustrates assembling the fluid handling and electrical subassemblies that are shown in Figures 2 and 3, respectively.

[0019] Figure 4B is a close-up cross-sectional view of the air gaps of the armature shown in Figure 4A.

[0020] Figure 5 is a flowchart of the method of assembling the modular fuel injector of the present invention.

#### **Detailed Description of the Preferred Embodiment**

[0021] Referring to Figures 1-4, a solenoid actuated fuel injector 100 dispenses a quantity of fuel that is to be combusted in an internal combustion engine (not shown). The fuel injector 100 extends along a longitudinal axis A-A between a first injector end 238 and a second injector end 239, and includes a valve group subassembly 200 and a power group subassembly 300. The valve group subassembly 200 performs fluid handling functions, e.g., defining a fuel flow path and prohibiting fuel flow through the injector 100. The power group subassembly 300 performs electrical functions, e.g., converting electrical signals to a driving force for permitting fuel flow through the injector 100.

[0022] Referring to Figures 1 and 2, the valve group subassembly 200 comprises a tube assembly extending along the longitudinal axis A-A between a first tube assembly end 200A and a second tube assembly end 200B. The tube assembly includes at least an inlet tube, a non-magnetic shell 230, and a valve body 240. The inlet tube 210 has a first inlet tube end proximate to the first tube assembly end 200A. A second end of the inlet tube 210 is connected to a first shell end of the non-magnetic shell 230. A second shell end of the non-magnetic shell 230 is connected to a first valve body end of the valve body 240. And a second valve body end of the valve body 240 is proximate to the second tube assembly end 200B. The inlet tube 210 can be formed by a deep drawing process or by a rolling operation. A pole piece can be integrally formed at the second inlet tube end of the inlet tube 210 or, as shown, a separate pole piece 220 can be connected to a partial inlet tube 210

and connected to the first shell end of the non-magnetic shell 230. The non-magnetic shell 230 can comprise non-magnetic stainless steel, e.g., 300 series stainless steels, or any other material that has similar structural and magnetic properties.

[0023] A seat 250 is secured at the second end of the tube assembly. The seat 250 defines an opening centered on the fuel injector's longitudinal axis A-A and through which fuel can flow into the internal combustion engine (not shown). The seat 250 includes a sealing surface surrounding the opening. The sealing surface, which faces the interior of the valve body 240, can be frustoconical or concave in shape, and can have a finished surface. An orifice plate 254 can be used in connection with the seat 250 to provide at least one precisely sized and oriented orifice in order to obtain a particular fuel spray pattern.

[0024] An armature assembly 260 is disposed in the tube assembly. The armature assembly 260 includes a first armature assembly end having a ferro-magnetic or armature portion 262 and a second armature assembly end having a sealing portion. The armature assembly 260 is disposed in the tube assembly such that the magnetic portion, or "armature," 262 confronts the pole piece 220. The sealing portion can include a closure member 264, e.g., a spherical valve element, that is moveable with respect to the seat 250 and its sealing surface 252. The closure member 264 is movable between a closed configuration, as shown in Figures 1 and 2, and an open configuration (not shown). In the closed configuration, the closure member 264 contiguously engages the sealing surface 252 to prevent fluid flow through the opening. In the open configuration, the closure member 264 is spaced from the seat 250 to permit fluid flow through the opening. The armature assembly 260 may also include a separate intermediate portion 266 connecting the ferro-magnetic or armature portion 262 to the closure member 264. The intermediate portion or armature tube 266 can be fabricated by various techniques, for example, a plate can be rolled and its seams welded or a blank can be deep-drawn to form a seamless tube. The intermediate portion 266 is preferable due to its ability to reduce magnetic flux leakage from the magnetic circuit of the fuel injector 100. This ability arises from the fact that the intermediate portion or armature tube 266 can be non-magnetic, thereby magnetically decoupling the magnetic portion or armature 262 from the ferro-magnetic closure member 264. Because the ferro-magnetic closure member is decoupled from the ferro-magnetic or armature 262, flux leakage is reduced, thereby improving the efficiency of the magnetic circuit.

[0025] To improve the armature's response, reduce wear on the impact surfaces and variations in the working air gap between the respective end portions 221 and 261, surface treatments can be applied to at least one of the end portions 221 and 261, as shown on Figures 2B and 2C. The surface treatments can include coating, plating or case-hardening. Coatings or platings can in-

clude, but are not limited to, hard chromium plating, nickel plating or keronite coating. Case hardening on the other hand, can include, but are not limited to, nitriding, carburizing, carbo-nitriding, cyaniding, flame, spark or induction hardening.

**[0026]** The surface treatments will typically form at least one layer of wear-resistant materials on the respective end portions. These layers, however, tend to be inherently thicker wherever there is a sharp edge, such as between junction between the circumference and the radial end face of either portions. Moreover, this thickening effect results in uneven contact surfaces at the radially outer edge of the end portions. However, by forming the wear-resistant layers on at least one of the end portions 221 and 261, where at least one end portion has a surface 263 generally oblique to longitudinal axis A-A, both end portions are now substantially in mating contact with respect to each other.

**[0027]** As shown in Figure 2B, the end portions 221 and 261 are generally symmetrical about the longitudinal axis A-A. As further shown in Figure 2C, the surface 263 of at least one of the end portions can be of a general conic, frustoconical, spheroidal or a surface generally oblique with respect to the axis A-A.

**[0028]** Since the surface treatments may affect the physical and magnetic properties of the ferromagnetic portion of the armature assembly 260 or the pole piece 220, a suitable material, e.g., a mask, a coating or a protective cover, surrounds areas other than the respective end portions 221 and 261 during the surface treatments. Upon completion of the surface treatments, the material is removed, thereby leaving the previously masked areas unaffected by the surface treatments.

**[0029]** The sealing portion can include a closure member 264, e.g., a spherical valve element, that is moveable with respect to the seat 250 and its sealing surface 252. The closure member 264 is movable between a closed configuration, as shown in Figures 1 and 2, and an open configuration (not shown). In the closed configuration, the closure member 264 contiguously engages the sealing surface 252 to prevent fluid flow through the opening. In the open configuration, the closure member 264 is spaced from the seat 250 to permit fluid flow through the opening. The armature assembly 260 may also include a separate intermediate portion 266 connecting the ferro-magnetic or armature portion 262 to the closure member 264.

**[0030]** At least one axially extending through-bore 267 and at least one aperture 268 through a wall of the armature assembly 260 can provide fuel flow through the armature assembly 260. The apertures 268, which can be of any shape, are preferably non-circular, e.g., axially elongated, to facilitate the passage of gas bubbles. For example, in the case of a separate intermediate portion 266 that is formed by rolling a sheet substantially into a tube, the apertures 268 can be an axially extending slit defined between non-abutting edges of the rolled sheet. The apertures 268 provide fluid com-

munication between the at least one through-bore 267 and the interior of the valve body 240. Thus, in the open configuration, fuel can be communicated from the through-bore 267, through the apertures 268 and the interior of the valve body 240, around the closure member 264, and through the opening into the engine (not shown).

**[0031]** In the case of a spherical valve element providing the closure member 264, the spherical valve element can be connected to the armature assembly 260 at a diameter that is less than the diameter of the spherical valve element. Such a connection would be on side of the spherical valve element that is opposite contiguous contact with the seat. A lower armature guide can be disposed in the tube assembly, proximate the seat, and would slidably engage the diameter of the spherical valve element. The lower armature guide can facilitate alignment of the armature assembly 260 along the axis A-A.

**[0032]** A resilient member 270 is disposed in the tube assembly and biases the armature assembly 260 toward the seat. A filter assembly 282 comprising a filter 284A and an adjusting tube 280 is also disposed in the tube assembly. The filter assembly 282 includes a first end and a second end. The filter 284A is disposed at one end of the filter assembly 282 and also located proximate to the first end of the tube assembly and apart from the resilient member 270 while the adjusting tube 280 is disposed generally proximate to the second end of the tube assembly. The adjusting tube 280 engages the resilient member 270 and adjusts the biasing force of the member with respect to the tube assembly. In particular, the adjusting tube 280 provides a reaction member against which the resilient member 270 reacts in order to close the injector valve 100 when the power group subassembly 300 is de-energized. The position of the adjusting tube 280 can be retained with respect to the inlet tube 210 by an interference fit between an outer surface of the adjusting tube 280 and an inner surface of the tube assembly. Thus, the position of the adjusting tube 280 with respect to the inlet tube 210 can be used to set a predetermined dynamic characteristic of the armature assembly 260. Alternatively, as shown in Figure 2A, a filter assembly 282' comprising adjusting tube 280A and inverted cup-shaped filtering element 284B can be utilized in place of the cone type filter assembly 282.

**[0033]** The valve group subassembly 200 can be assembled as follows. The non-magnetic shell 230 is connected to the inlet tube 210 and to the valve body 240. The filter assembly 282 or 282' is inserted along the axis A-A from the first inlet tube end of the inlet tube 210. Next, the resilient member 270 and the armature assembly 260 (which was previously assembled) are inserted along the axis A-A from the second valve body end of the valve body 240. The filter assembly 282 or 282' can be inserted into the inlet tube 210 to a predetermined distance so as to abut the resilient member.

The position of the filter assembly 282 or 282' with respect to the inlet tube 210 can be used to adjust the dynamic properties of the resilient member, e.g., so as to ensure that the armature assembly 260 does not float or bounce during injection pulses.

**[0034]** The seat 250 and orifice disk 254 are then inserted along the axis A-A from the second valve body end of the valve body 240. As shown in Figures 2D or 2E, respectively, a lift sleeve 255 or a crush ring 256 can be used to set the injector lift height. Although the lift sleeve 255 or the crush ring 256 is interchangeable, the lift sleeve 255 is preferable since adjustments can be made by moving the lift sleeve axially in either direction along axis A-A. At this time, a probe can be inserted from either the inlet tube end 200A or the outlet tube end 200B to check for the lift of the injector. If the injector lift is correct, the lift sleeve 255 and the seat 250 are fixedly attached to the valve body 240. It should be noted here that both the seat 250 and the lift sleeve 255 are fixedly attached to the valve body 240 by known conventional attachment techniques, including, for example, laser welding, crimping, and friction welding or conventional welding, and preferably laser welding. Thereafter, the seat 250 and orifice plate 254 can be fixedly attached to one another or to the valve body 240 by known attachment techniques such as laser welding, crimping, friction welding, conventional welding, etc.

**[0035]** Referring to Figures 1 and 3, the power group subassembly 300 comprises an electromagnetic coil 310, at least one terminals 320, a housing 330, and an overmold 340. The electromagnetic coil 310 comprises a wire that can be wound on a bobbin 314 and electrically connected to electrical contact 322 on the bobbin 314. When energized, the coil generates magnetic flux that moves the armature assembly 260 toward the open configuration, thereby allowing the fuel to flow through the opening. De-energizing the electromagnetic coil 310 allows the resilient member 270 to return the armature assembly 260 to the closed configuration, thereby shutting off the fuel flow. Each electrical terminal 320 is in electrical communication with a respective electrical contact 322 of the coil 310. The housing 330, which provides a return path for the magnetic flux, generally comprises a ferromagnetic cylinder 332 surrounding the electromagnetic coil 310 and a flux washer 334 extending from the cylinder toward the axis A-A. The washer 334 can be integrally formed with or separately attached to the cylinder. The housing 330 can include holes, slots, or other features to breakup eddy currents that can occur when the coil is de-energized. The overmold 340 maintains the relative orientation and position of the electromagnetic coil 310, the at least one electrical terminals 320 (two are used in the illustrated example), and the housing 330. The overmold 340 covers electrical connector portions 324 in which a portion of the terminals 320 are exposed. The terminals 320 and the electrical connector portions 324 can engage a mating connector, e.g., part of a vehicle wiring harness (not shown),

to facilitate connecting the injector 100 to an electrical power supply (not shown) for energizing the electromagnetic coil 310.

**[0036]** According to a preferred embodiment, the magnetic flux generated by the electromagnetic coil 310 flows in a circuit that comprises, the pole piece 220, a working air gap between the pole piece 220 and the magnetic armature portion 262, across a parasitic air gap between the magnetic armature portion 262 and the valve body 240, the housing 330, and the flux washer 334.

**[0037]** The coil group subassembly 300 can be constructed as follows. A plastic bobbin 314 can be molded with at least one electrical contact 322. The wire 312 for the electromagnetic coil 310 is wound around the plastic bobbin 314 and connected to the electrical contacts 322. The housing 330 is then placed over the electromagnetic coil 310 and bobbin 314. A terminal 320, which is pre-formed to a proper shape, is then electrically connected to each electrical contact 322. An overmold 340 is then formed to maintain the relative assembly of the coil/bobbin unit, housing 330, and terminal 320. The overmold 340 also provides a structural case for the injector and provides predetermined electrical and thermal insulating properties. A separate collar can be connected, e.g., by bonding, and can provide an application specific characteristic such as an orientation feature or an identification feature for the injector 100. Thus, the overmold 340 provides a universal arrangement that can be modified with the addition of a suitable collar. To reduce manufacturing and inventory costs, the coil/bobbin unit can be the same for different applications. As such, the terminal 320 and overmold 340 (or collar, if used) can be varied in size and shape to suit particular tube assembly lengths, mounting configurations, electrical connectors etc.

**[0038]** Alternatively, as shown in Fig. 3A, a two-piece overmold allows for a first overmold 341 that is application specific while the second overmold 342 can be for all applications. The first overmold 341 is bonded to a second overmold 342, allowing both to act as electrical and thermal insulators for the injector. Additionally, a portion of the housing 330 can extend axially beyond an end of the overmold 340 and can be formed with a flange to retain an O-ring.

**[0039]** Alternatively, as shown in Fig. 3A, a two-piece overmold can be used instead of the one-piece overmold 340. The two-piece overmold allow for a first overmold 341 that is application specific while the second overmold 342 can be for all applications. The first overmold is bonded to a second overmold, allowing both to act as electrical and thermal insulators for the injector. Additionally, a portion of the housing 330 can project beyond the over-mold or to allow the injector to accommodate different injector tip lengths.

**[0040]** As is particularly shown in Figures 1 and 4, the valve group subassembly 200 can be inserted into the coil group subassembly 300. To ensure that the two su-



bassemblies are fixed in a proper axial orientation, shoulders 222A of the pole piece 220 engages corresponding shoulders 222B of the coil subassembly. Next, the resilient member 270 is inserted from the inlet end of the inlet tube 210. Thus, the injector 100 is made of two modular subassemblies that can be assembled and tested separately, and then connected together to form the injector 100. The valve group subassembly 200 and the coil group subassembly 300 can be fixedly attached by adhesive, welding, or another equivalent attachment process. According to a preferred embodiment, a hole 360 through the overmold exposes the housing 330 and provides access for laser welding the housing 330 to the valve body 240.

**[0041]** The first injector end 238 can be coupled to the fuel supply of an internal combustion engine (not shown). The O-ring can be used to seal the first injector end 238 to the fuel supply so that fuel from a fuel rail (not shown) is supplied to the tube assembly, with the O-ring making a fluid tight seal, at the connection between the injector 100 and the fuel rail (not shown).

**[0042]** In operation, the electromagnetic coil 310 is energized, thereby generating magnetic flux in the magnetic circuit. The magnetic flux moves armature assembly 260 (along the axis A-A, according to a preferred embodiment) towards the integral pole piece 220 50, i.e., closing the working air gap. This movement of the armature assembly 260 separates the closure member 264 from the seat 250 and allows fuel to flow from the fuel rail (not shown), through the inlet tube, the through-bore 267, the elongated openings and the valve body 240, between the seat 250 and the closure member 264, through the opening, and finally through the orifice plate 254 into the internal combustion engine (not shown). When the electromagnetic coil 310 is de-energized, the armature assembly 260 is moved by the bias of the resilient member 270 to contiguously engage the closure member 264 with the seat, and thereby prevent fuel flow through the injector 100.

**[0043]** Referring to Figure 5, a preferred assembly process can be as follows:

1. A pre-assembled valve body and non-magnetic sleeve is located with the valve body oriented up.
2. A screen retainer, e.g., a lift sleeve, is loaded into the valve body/non-magnetic sleeve assembly.
3. A lower screen can be loaded into the valve body/non-magnetic sleeve assembly.
4. A pre-assembled seat and guide assembly is loaded into the valve body/non-magnetic sleeve assembly.
5. The seat/guide assembly is pressed to a desired position within the valve body/non-magnetic sleeve assembly.
6. The valve body is welded, e.g., by a continuous wave laser forming a hermetic lap seal, to the seat.
7. A first leak test is performed on the valve body/non-magnetic sleeve assembly. This test can be

performed pneumatically.

8. The valve body/non-magnetic sleeve assembly is inverted so that the non-magnetic sleeve is oriented up.

9. An armature assembly is loaded into the valve body/non-magnetic sleeve assembly.

10. A pole piece is loaded into the valve body/non-magnetic sleeve assembly and pressed to a pre-lift position.

11. Dynamically, e.g., pneumatically, purge valve body/non-magnetic sleeve assembly.

12. Set lift.

13. The non-magnetic sleeve is welded, e.g., with a tack weld, to the pole piece.

14. The non-magnetic sleeve is welded, e.g., by a continuous wave laser forming a hermetic lap seal, to the pole piece.

15. Verify lift

16. A spring is loaded into the valve body/non-magnetic sleeve assembly.

17. A filter/adjusting tube is loaded into the valve body/non-magnetic sleeve assembly and pressed to a pre-cal position.

18. An inlet tube is connected to the valve body/non-magnetic sleeve assembly to generally establish the fuel group subassembly.

19. Axially press the fuel group subassembly to the desired over-all length.

20. The inlet tube is welded, e.g., by a continuous wave laser forming a hermetic lap seal, to the pole piece.

21. A second leak test is performed on the fuel group subassembly. This test can be performed pneumatically.

22. The fuel group subassembly is inverted so that the seat is oriented up.

23. An orifice is punched and loaded on the seat.

24. The orifice is welded, e.g., by a continuous wave laser forming a hermetic lap seal, to the seat.

25. The rotational orientation of the fuel group subassembly/orifice can be established with a "look/orient/look" procedure.

26. The fuel group subassembly is inserted into the (pre-assembled) power group subassembly.

27. The power group subassembly is pressed to a desired axial position with respect to the fuel group subassembly.

28. The rotational orientation of the fuel group subassembly/orifice/power group subassembly can be verified.

29. The power group subassembly can be laser marked with information such as part number, serial number, performance data, a logo, etc.

30. Perform a high-potential electrical test.

31. The housing of the power group subassembly is tack welded to the valve body.

32. A lower O-ring can be installed. Alternatively, this lower O-ring can be installed as a post test op-

eration.

33. An upper O-ring is installed.

34. Invert the fully assembled fuel injector.

35. Transfer the injector to a test rig.

**[0044]** To set the lift, i.e., ensure the proper injector lift distance, there are at least four different techniques that can be utilized. According to a first technique, a crush ring 256 that is inserted into the valve body 240 between the lower guide 257 and the valve body 240 can be deformed. According to a second technique, the relative axial position of the valve body 240 and the non-magnetic shell 230 can be adjusted before the two parts are affixed together. According to a third technique, the relative axial position of the non-magnetic shell 230 and the pole piece 220 can be adjusted before the two parts are affixed together. And according to a fourth technique, a lift sleeve 255 can be displaced axially within the valve body 240. If the lift sleeve technique is used, the position of the lift sleeve can be adjusted by moving the lift sleeve axially. The lift distance can be measured with a test probe. Once the lift is correct, the sleeve is welded to the valve body 240, e.g., by laser welding. Next, the valve body 240 is attached to the inlet tube 210 assembly by a weld, preferably a laser weld. The assembled fuel group subassembly 200 is then tested, e.g., for leakage.

**[0045]** As is shown in Figure 5, the lift set procedure may not be able to progress at the same rate as the other procedures. Thus, a single production line can be split into a plurality (two are shown) of parallel lift setting stations, which can thereafter be recombined back into a single production line.

**[0046]** The preparation of the power group subassembly, which can include (a) the housing 330, (b) the bobbin assembly including the terminals 320, (c) the flux washer 334, and (d) the overmold 340, can be performed separately from the fuel group subassembly.

**[0047]** According to a preferred embodiment, wire 312 is wound onto a pre-formed bobbin 314 with at least one electrical contact 322 molded thereon. The bobbin assembly is inserted into a pre-formed housing 330. To provide a return path for the magnetic flux between the pole piece 220 and the housing 330, flux washer 334 is mounted on the bobbin assembly. A pre-bent terminal 320 having axially extending connector portions 324 are coupled to the electrical contact portions 322 and brazed, soldered welded, or preferably resistance welded. The partially assembled power group assembly is now placed into a mold (not shown). By virtue of its pre-bent shape, the terminals 320 will be positioned in the proper orientation with the harness connector 321 when a polymer is poured or injected into the mold. Alternatively, two separate molds (not shown) can be used to form a two-piece overmold as described with respect to Figure 3A. The assembled power group subassembly 300 can be mounted on a test stand to determine the solenoid's pull force, coil resistance and the drop in volt-

age as the solenoid is saturated.

**[0048]** The inserting of the fuel group subassembly 200 into the power group subassembly 300 operation can involve setting the relative rotational orientation of fuel group subassembly 200 with respect to the power group subassembly 300. The inserting operation can be accomplished by one of two methods: "top-down" or "bottom-up." According to the former, the power group subassembly 300 is slid downward from the top of the fuel group subassembly 200, and according to the latter, the power group subassembly 300 is slid upward from the bottom of the fuel group subassembly 200. In situations where the inlet tube 210 assembly includes a flared first end, bottom-up method is required. Also in these situations, the O-ring 290 that is retained by the flared first end can be positioned around the power group subassembly 300 prior to sliding the fuel group subassembly 200 into the power group subassembly 300. After inserting the fuel group subassembly 200 into the power group subassembly 300, these two subassemblies are affixed together, e.g., by welding, such as laser welding. According to a preferred embodiment, the overmold 340 includes an opening 360 that exposes a portion of the housing 330. This opening 360 provides access for a welding implement to weld the housing 330 with respect to the valve body 240. Of course, other methods of affixing the subassemblies with respect to one another can be used. Finally, the O-ring 290 at either end of the fuel injector can be installed.

**[0049]** The method of assembling the preferred embodiments, and the preferred embodiments themselves, are believed to provide manufacturing advantages and benefits. For example, because of the modular arrangement only the valve group subassembly is required to be assembled in a "clean" room environment. The power group subassembly 300 can be separately assembled outside such an environment, thereby reducing manufacturing costs. Also, the modularity of the subassemblies permits separate pre-assembly testing of the valve and the coil assemblies. Since only those individual subassemblies that test unacceptable are discarded, as opposed to discarding fully assembled injectors, manufacturing costs are reduced. Further, the use of universal components (e.g., the coil/bobbin unit, non-magnetic shell 230, seat 250, closure member 264, filter/retainer assembly 282, etc.) enables inventory costs to be reduced and permits a "just-in-time" assembly of application specific injectors. Only those components that need to vary for a particular application, e.g., the terminals 320 and inlet tube 210 need to be separately stocked. Another advantage is that by locating the working air gap, i.e., between the armature assembly 260 and the pole piece 220, within the electromagnetic coil 310, the number of windings can be reduced. In addition to cost savings in the amount of wire 312 that is used, less energy is required to produce the required magnetic flux and less heat builds-up in the coil (this heat must be dissipated to ensure consistent operation

of the injector). Yet another advantage is that the modular construction enables the orifice disk 254 to be attached at a later stage in the assembly process, even as the final step of the assembly process. This just-in-time assembly of the orifice disk 254 allows the selection of extended valve bodies depending on the operating requirement. Further advantages of the modular assembly include out-sourcing construction of the power group subassembly 300, which does not need to occur in a clean room environment. And even if the power group subassembly 300 is not out-sourced, the cost of providing additional clean room space is reduced.

[0050] While the preferred embodiments have been disclosed with reference to certain embodiments, numerous modifications, alterations, and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims, and equivalents thereof.

#### Claims

1. A fuel injector for use with an internal combustion engine, the fuel injector comprising:

a valve group subassembly including:

a tube assembly having a longitudinal axis extending between a first end and a second end, the tube assembly including an inlet tube having an inlet tube face;  
 a seat secured at the second end of the tube assembly, the seat defining an opening;  
 a lift sleeve telescopically disposed within the tube assembly a predetermined distance to set a relative axial position between the seat and the tube assembly;  
 an armature assembly disposed within the tube assembly, the armature assembly having an armature face, at least one of the armature face and the inlet tube face having a first portion generally oblique to the longitudinal axis;  
 a member biasing the armature assembly toward the seat;  
 an adjusting tube located in the tube assembly, the adjusting tube engaging the member and adjusting a biasing force of the member;  
 a first attaching portion; and

a coil group subassembly including:

a solenoid coil operable to displace the armature assembly with respect to the seat; and  
 a second attaching portion fixedly connected to the first attaching portion.

2. The fuel injector according to claim 1, further comprising:

a filter located at least within the tube assembly, the filter having retaining portion.

3. The fuel injector according to claim 2, further comprising:

an O-ring circumscribing the first end of the tube assembly, the retaining portion of the filter maintaining the O-ring proximate the first end of the tube assembly.

4. The fuel injector according to claim 2, wherein the filter is conical with respect to the longitudinal axis.

5. The fuel injector according to claim 2, wherein the filter has a cup shape and has an open filter end and a closed filter end.

6. The fuel injector according to claim 5, wherein the open filter end is disposed toward the seat.

7. The fuel injector according to claim 1, wherein the first portion is generally arcuate.

8. The fuel injector according to claim 1, wherein the first portion is generally frustoconical.

9. The fuel injector according to claim 1, wherein the armature face is hardened.

10. The fuel injector according to claim 9, wherein the armature face is heat treated.

11. The fuel injector according to claim 9, wherein the armature face is plated.

12. The fuel injector according to claim 1, wherein the inlet tube has a first tube portion and a second tube portion connected to the first tube portion.

13. The fuel injector according to claim 1, wherein the tube assembly further comprises a non-magnetic shell, the non-magnetic shell includes a guide extending from the non-magnetic shell toward the longitudinal axis.

14. The fuel injector according to claim 1, further comprising:

a lower armature guide disposed proximate the seat, the lower armature guide aligning the armature assembly along the longitudinal axis.

15. The fuel injector according to claim 1, wherein the coil group subassembly further includes: 5

a first insulator portion generally surrounding the first end of the tube assembly; and  
a second insulator portion generally surrounding the second end of the tube assembly, the first insulator portion being bonded to the second insulator portion.

16. The fuel injector according to claim 1, wherein the valve group subassembly is symmetric about the longitudinal axis. 15

17. The fuel injector according to claim 16, wherein the tube assembly includes a valve body and a shell, the valve body engages the shell in a plane generally transverse to the longitudinal axis. 20

18. The fuel injector according to claim 16, wherein the tube assembly includes a valve body and a shell, the valve body engages the shell along an annular surface generally parallel to the longitudinal axis. 25

19. A method of manufacturing a fuel injector, comprising: 30

providing a valve group subassembly including:

a tube assembly having a longitudinal axis extending between a first end and a second end, the tube assembly including an inlet tube having an inlet tube face; 35

a seat secured at the second end of the tube assembly, the seat defining an opening; 40

a lift sleeve telescopically disposed within the tube assembly a predetermined distance to set a relative axial position between the seat and the tube assembly; 45

an armature assembly disposed within the tube assembly, the armature assembly having an armature face, at least one of the armature face and the inlet tube face having a first portion generally oblique to the longitudinal axis; 50

a member biasing the armature assembly toward the seat;

an adjusting tube located in the tube assembly, the adjusting tube engaging the member and adjusting a biasing force of the member; 55

a first attaching portion; providing a coil group subassembly including:

a solenoid coil operable to displace the armature assembly with respect to the seat; and

a second attaching portion; inserting the valve group subassembly into the coil group subassembly; and connecting the first and second attaching portions together.

20. The method according to claim 19, wherein the armature includes at least one radial facing surface, the method further comprising:

masking the at least one radial facing surface; and  
hardening the armature face.

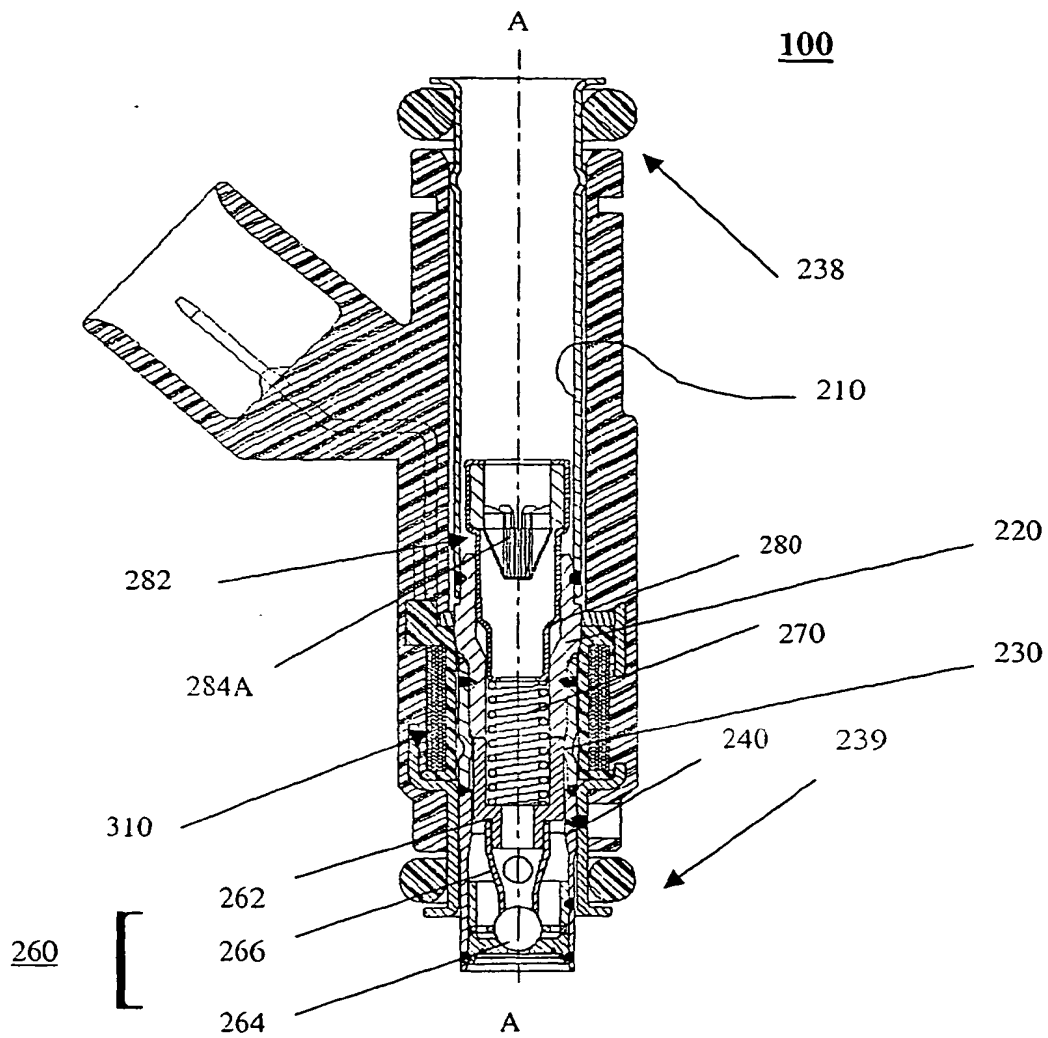


FIG. 1

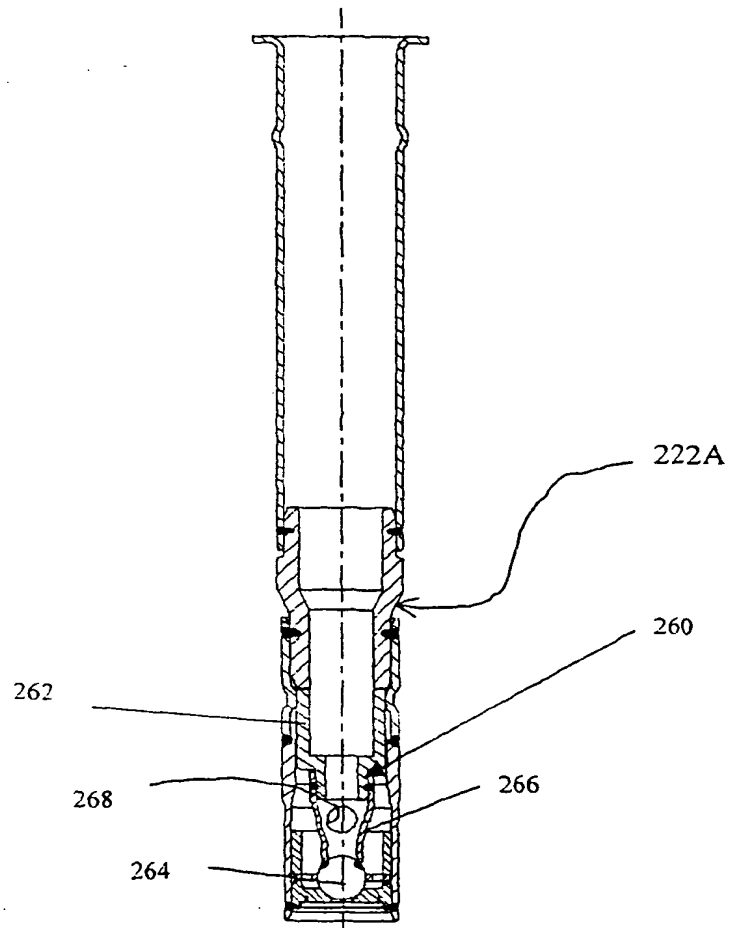


FIG. 2

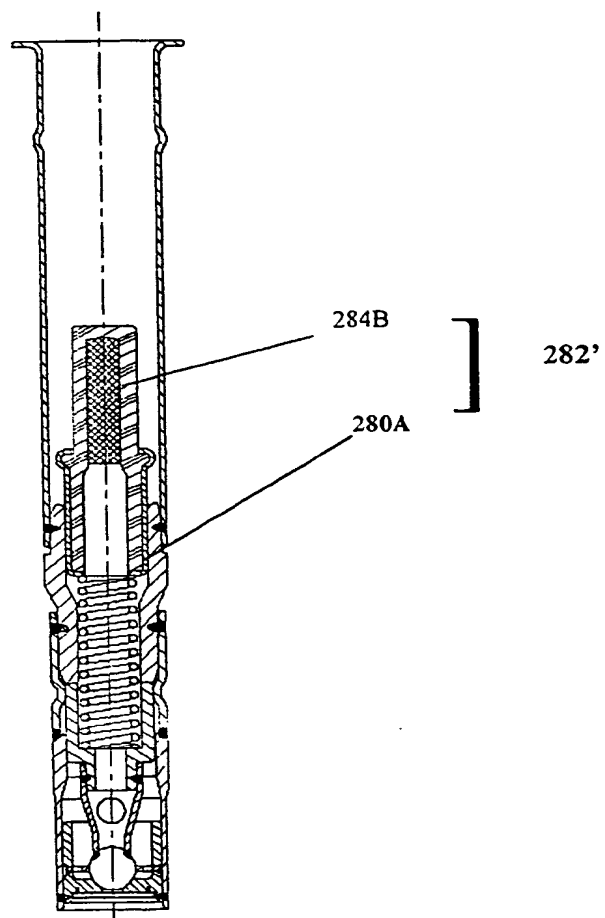
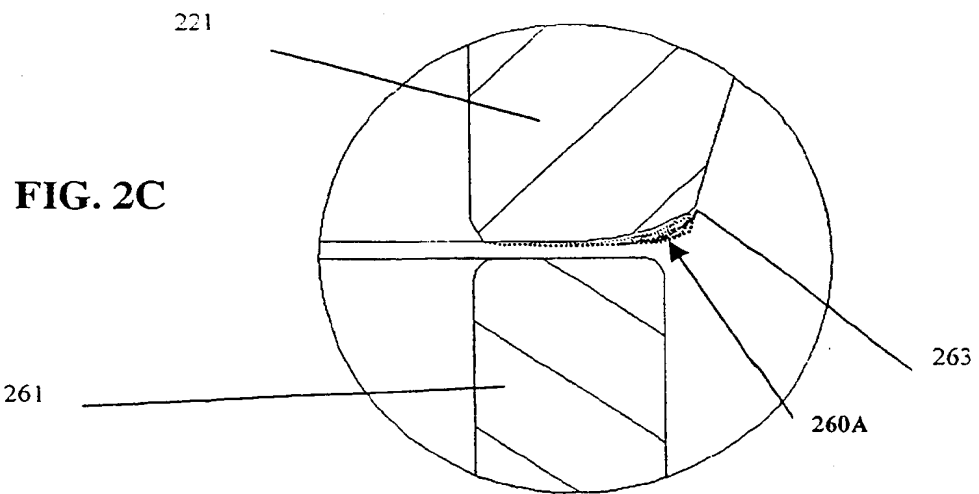
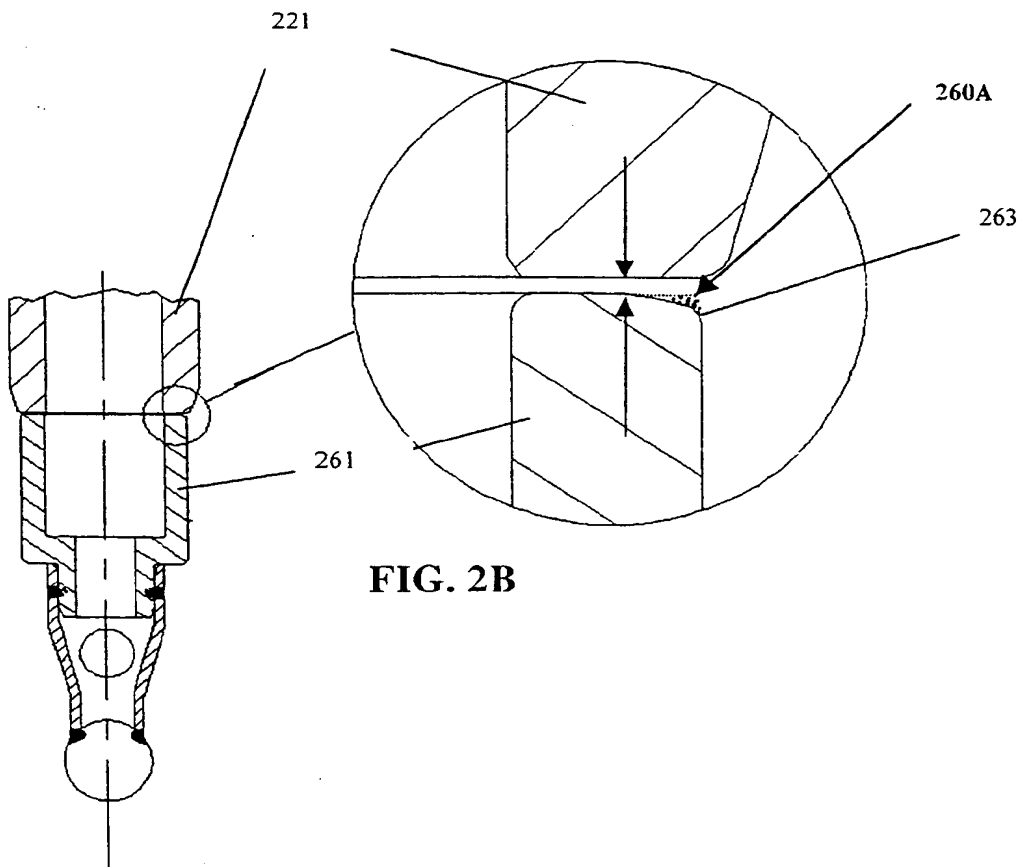


FIG. 2A





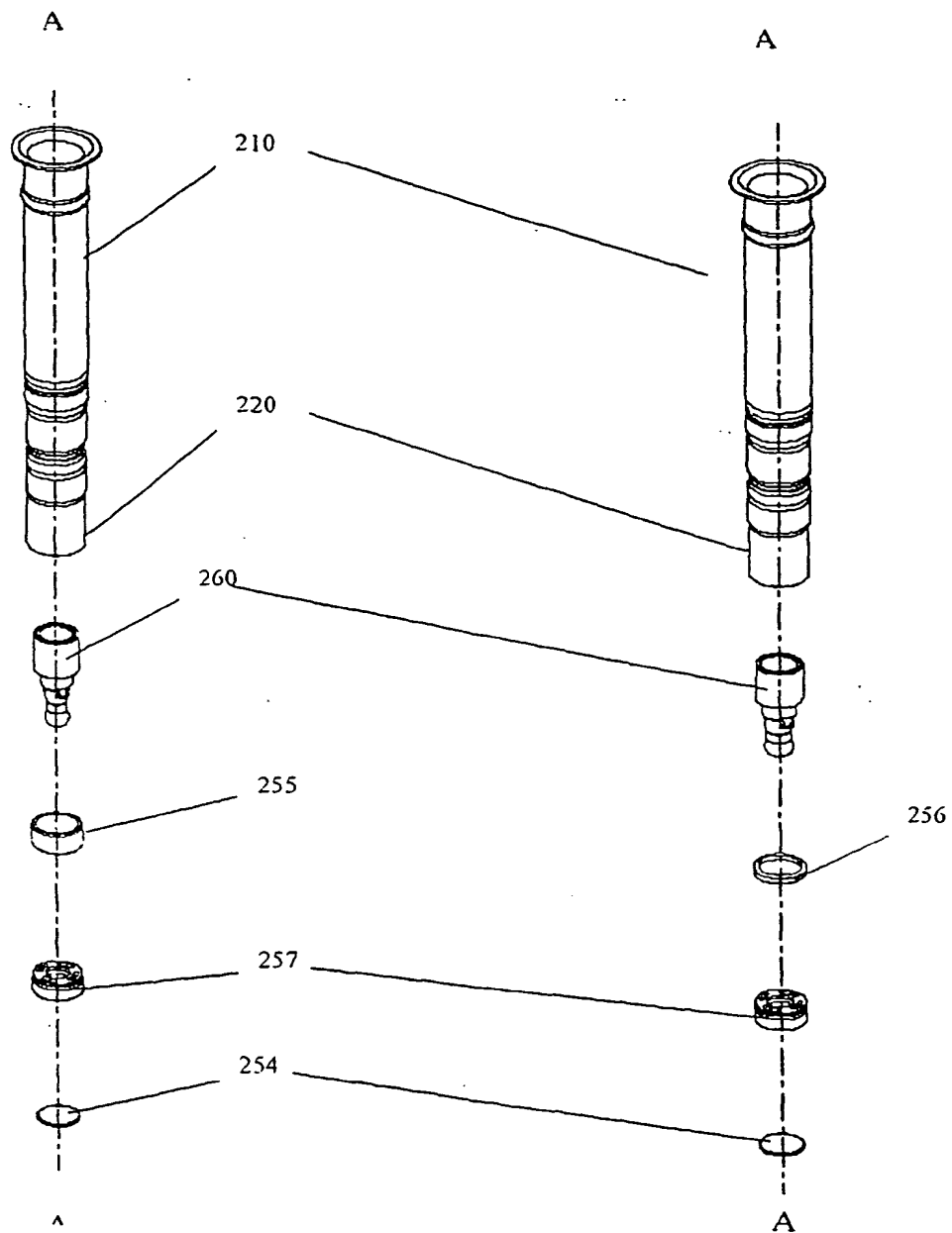


FIG. 2C

FIG. 2D

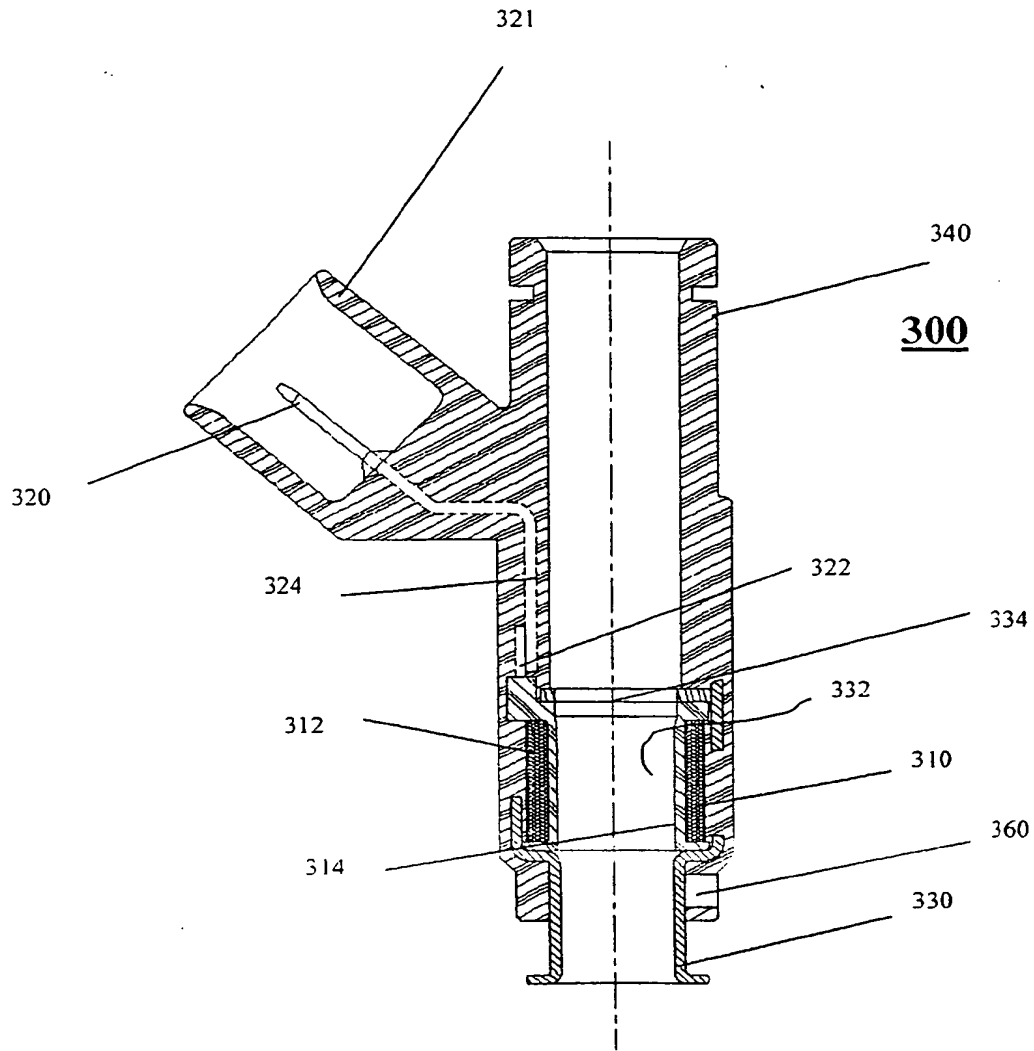


FIG. 3

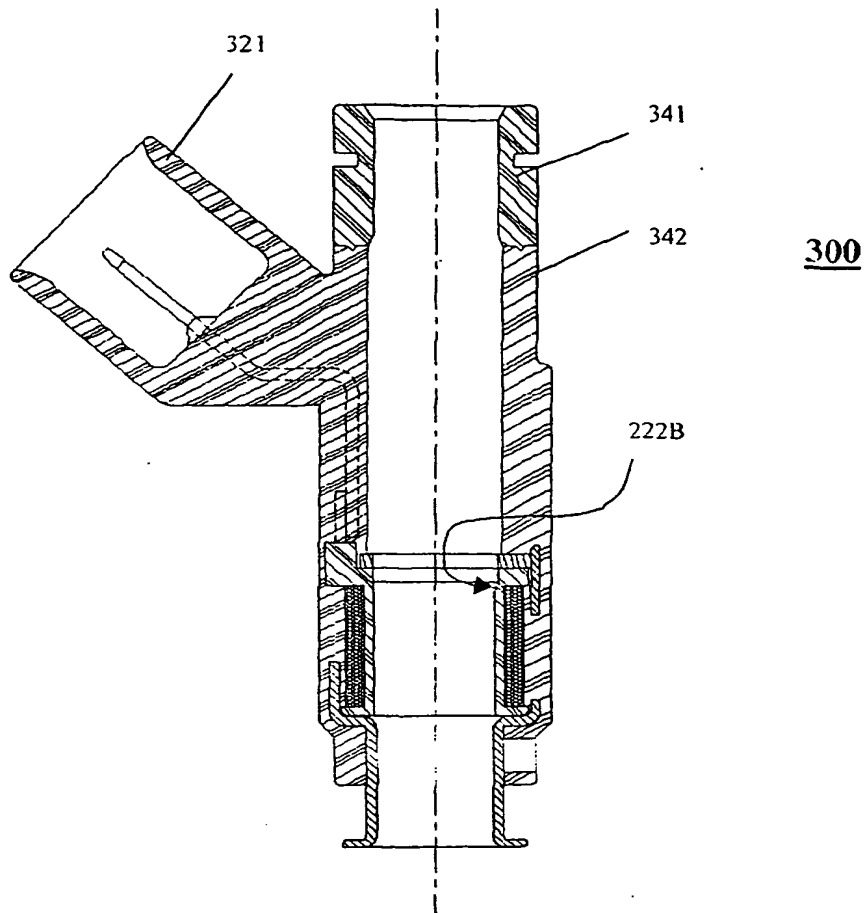


FIG. 3A

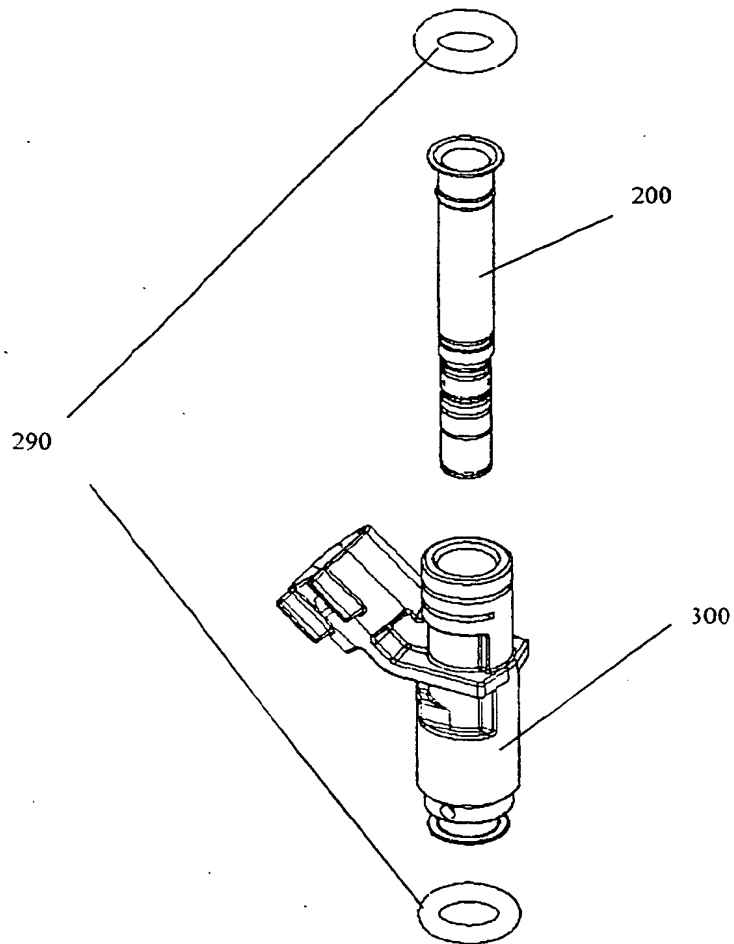


FIG. 4

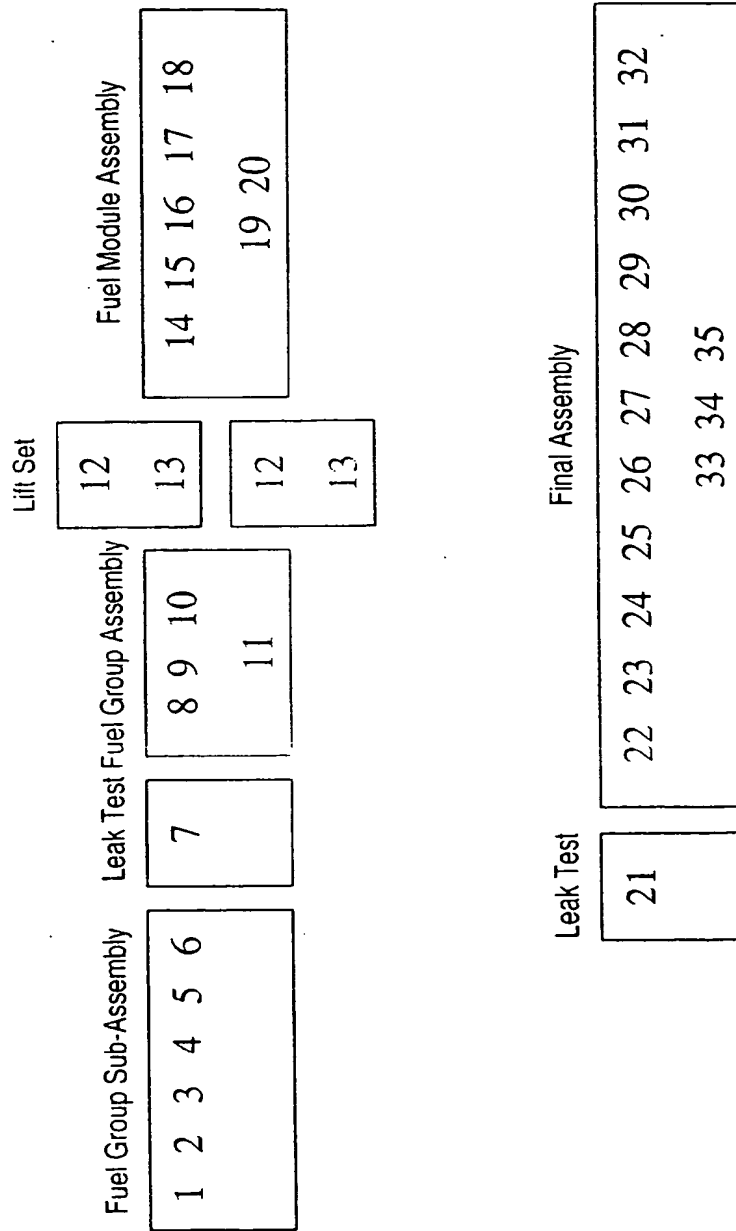


FIG. 5



European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 01 20 4758

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The present search report has been drawn up for all claims			
Place of search <b>MUNICH</b>		Date of completion of the search <b>26 March 2002</b>	Examiner <b>Kolland, U</b>
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone  Y : particularly relevant if combined with another document of the same category  A : technological background  O : non-written disclosure  P : intermediate document</p> <p>T : theory or principle underlying the invention  E : earlier patent document, but published on, or after the filing date  D : document cited in the application  L : document cited for other reasons  &amp; : member of the same patent family, corresponding document</p>			

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